

GENERAL INFORMATION

Office Hours	1014 Pupin, tel. 4-2554. Drop in any time, or make an appointment.
Required Text	<i>Radiative Processes in Astrophysics</i> , by G. R. Rybicki & A. P. Lightman.
Supplementary Texts	<i>The Physics of Astrophysics Volume I: Radiation</i> , by Frank H. Shu. <i>Physics of the Interstellar and Intergalactic Medium</i> , by Bruce T. Draine.
Homework	Homework problems will be assigned and graded weekly. They will usually be due on Wednesdays. Homework will count for approximately 60% of the grade.
Exams	There will be one in-class midterm, and a three-hour final exam. The midterm and final will count for approximately 10% and 30% of the grade, respectively.
Course Web Page	http://user.astro.columbia.edu/~jules/GR6001/ Contains all handouts including homework assignments.

SYLLABUS

Approximately 75% of the following topics are typically covered.

Radiative Transfer

Specific intensity I_ν and its moments (J_ν, F_ν, P_ν)
Digression on pressure tensor, momentum flux, shear
Absorption and emission coefficients
Optical depth τ_ν , source function S_ν
Equation of radiative transfer and its formal solution
Distinction between blackbody radiation and thermal radiation
Rayleigh-Jeans Law, brightness temperature
Einstein coefficients, line profile function
Spin Temperature of HI 21 cm radiation
Scattering coefficients
Random walk with scattering and absorption
Radiative transfer in plane parallel geometry
Semi-infinite atmosphere, limb darkening
Radiative diffusion in plane-parallel geometry, Rosseland mean opacity
Eddington approximation, two-stream approximation
Simple model of greenhouse effect

Applications of Radiation Theory

Polarization and Stokes parameters (I, Q, U, V)
Birefringence
Design of dual-beam polarimeters for linear and circular polarization

Radiation by Accelerated Charges

Radiation from non-relativistic charges
Dipole approximation, Larmor's formula
Thomson Scattering
Polarization of Thomson scattered radiation
Rayleigh Scattering, blue sky
Conductivity, wave equation with damping
Dust scattering, absorption, and polarization
Extinction curves
Radiation from harmonically bound charges
Driven harmonic oscillator with damping, and its limiting cases
Lorentzian (damping) profile, natural line width
Curve of growth, Doppler and Voigt profiles
Damped Lyman α absorbers

Special Relativity and Applications

Lorentz transformations
Transformation of velocities, acceleration
Doppler effect
Four-vectors and applications
Emission from relativistic particles
Lorentz invariance of phase-space density, I_ν/ν^3
Relativistic beaming, superluminal motion
Diffusive shock acceleration (1st order Fermi acceleration)
Cosmic-ray acceleration in SNRs

Synchrotron Radiation

Cyclotron radiation and its polarization
Synchrotron emission
Synchrotron lifetime
Spectrum of synchrotron radiation $F(\omega/\omega_c)$
Polarization of synchrotron radiation
Synchrotron radiation from a power-law distribution of electrons
Crab Nebula diagnostics
Synchrotron self-absorption
Equipartition of energy, compact radio sources

Bremsstrahlung

Dipole approximation and small-angle scattering of single electrons
Thermal bremsstrahlung
Free-free absorption
Bethe-Bloch formula for relativistic ionization losses (not this year)
Measuring cosmic-ray composition (not this year)

Compton Scattering

Inverse Compton scattering
Total power
Inverse Compton scattering spectra, non-thermal and thermal

Compton γ -parameter, multiple Compton scattering
Comptonized blackbody spectrum
Inverse Compton catastrophe, maximum brightness temperature

Plasma Effects

Waves in a conducting plasma
Plasma frequency
Group velocity and phase velocity
Pulsar dispersion measure
Faraday rotation

Atomic Structure

One-electron atom
Magnetic quantum number
Angular momentum quantum number
Antisymmetry of wave functions
Addition of angular momentum
Fine-structure splitting (spin-orbit coupling)
Multi-electron atoms
Spectroscopic terms
Hyperfine structure
Zeeman effect (normal)
Circular polarization of 21 cm radiation
Anomalous Zeeman effect
Paschen-Back effect
Quadratic Zeeman effect, magnetic white dwarfs

(Dipole) Radiative Transitions

Electromagnetic Hamiltonian
Dipole approximation
Oscillator strengths for levels and multiplets
Transition rates
Electric dipole selection rules
Bound-free transitions
Raman scattering - symbiotic stars

Molecular Structure

Hamiltonian for a molecule
The simplest molecule, H_2^+
The H_2 molecule
Pure rotation spectra
Rotation-vibration spectra
Electronic-rotation-vibration spectra and selection rules